10   POTASSIUM

In most soils potassium is present in much larger amounts than nitrogen and phosphorus; the earth's crust contains about 1.9% K and 0.11% P. The potassium content in surface soil may vary from a few hundred kilograms per hectare in light, sandy soils to about 50,000 kilograms per hectare in heavy, clayey soils rich in micas and 2:1 layer silicates. In addition to larger amounts, potassium offers two more contrasts to nitrogen and phosphorus in soils. These are (1) almost all potassium is present in inorganic form, and (2) potassium is fairly well distributed throughout the profile, and in some cases subsoils may even have more potassium than surface soils (Figure 10.1).

10.1. FORMS OF SOIL POTASSIUM

Potassium is present in soils in four different forms, namely, primary-mineral, fixed, exchangeable, and solution K. These four forms of K are interrelated as shown in Figure 10.2. Normally, there is essentially no organic form of K in soils. Potassium contained in manures and crop residues returned to soils is rapidly leached out of the organic material and is dissolved in the soil solution, where it can react with the clay minerals.

10.1.1. Primary-Mineral K

The potassium bearing minerals in soils are the feldspars, orthoclase $[(K,Na)AlSi_3O_8]$ and microline $[Na,K)AlSiO_4]$, and the micas, muscovite $[KAl_3Si_3O_{10}(OH)_2]$, biotite $[K(Mg,Fe)_3AlSi_3O_{10}(OH)_2]$, and phlogopite $[KMg_3 Al Si_3 O_{10} (OH)_2]$. While feldspars are generally present in the coarser fraction of soil, micas are predominantly in the clay fraction (Table 10.1). Potassium in mineral form in soils may vary from 5000 to 25,000 mg K kg^{-1} soil (0.5 to 2.5%) (Tisdale et al., 1985).

10.1.2. Nonexchangeable or Fixed K

Nonexchangeable K is distinct from mineral K in that it is not bonded covalently within the crystal structure of soil mineral particles; instead, it is
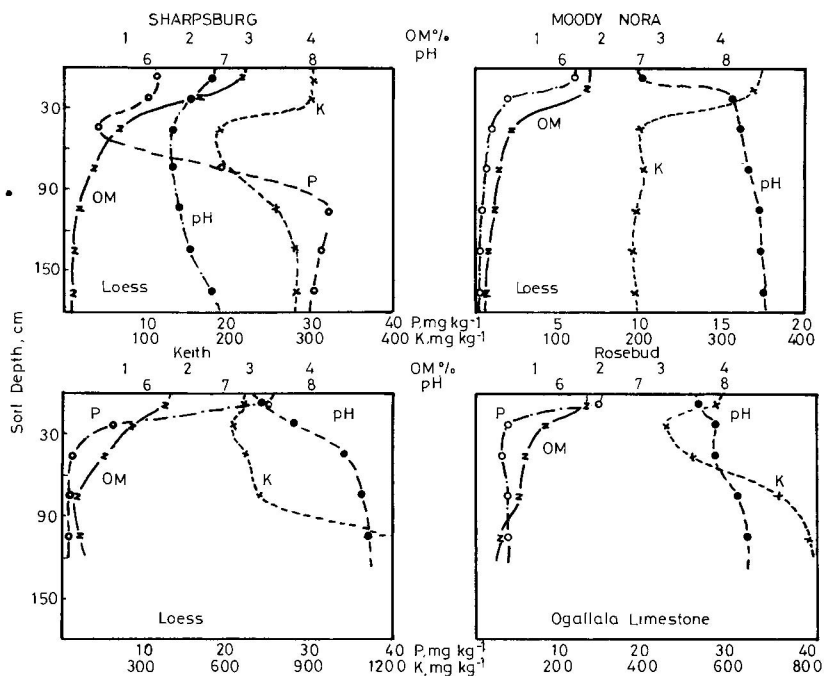
Figure 10.1. Distribution of organic matter, available P, available K, and pH in some Nebraska soils. (From McCallister et al., 1987. Soil Sci. Soc. Am. J. 51:1646. With permission of SSSA.)

held between adjacent tetrahedral layers of micas, vermiculites, and intergrade minerals (Sparks, 1987). Micas (muscovite, biotite, and phlogopite) have K fixed in the interlayer spaces (see Chapter 4). Bonding of K is stronger in dioctahedral mica (muscovite) than in tri-octahedral micas (biotite and phlogopite). Weathering of micas releases K in soils. Due to the variation in binding strength, the rate of release of K from different micas differs. The rate of potassium liberation from biotite is 13 to 16 and 75 to 105 times faster than from phlogopite and muscovite, respectively (Huang et al., 1968). The sequence of K release from K-bearing minerals by oxalic or citric acid has been found to be as follows: biotite > microline ≈ orthoclase > muscovite (Table 10.2).

Because micas have their entire negative charge satisfied by K (Chapter 4), the release of K results in the formation of secondary clay minerals such as illite (hydrous micas) and vermiculite, with accompanying gain of water or OH_3^+ and swelling of the lattice (Figure 10.3). Once this happens, K changes from a non-exchangeable form to an exchangeable form. Depletion of K from soil solution by plants or by leaching lowers the K concentration in solution and induces the liberation of interlayer, fixed K. In one of our unpublished
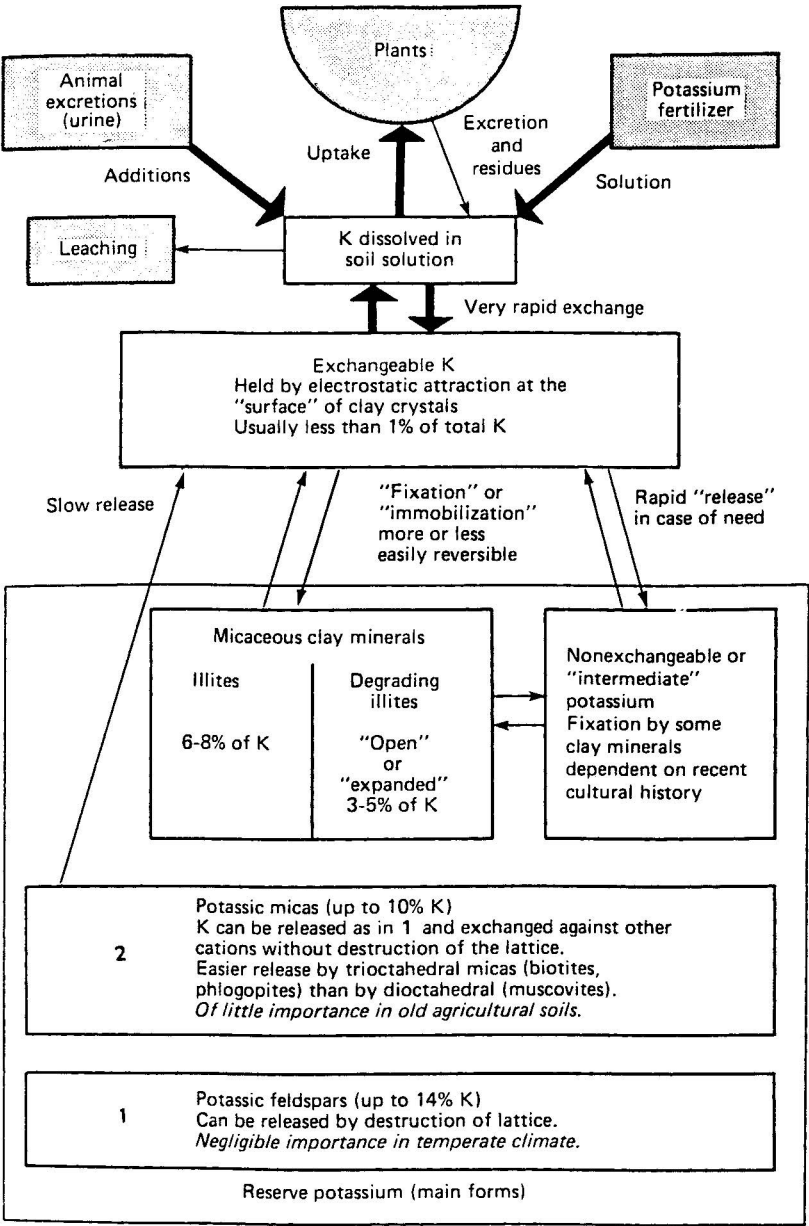
Figure 10.2. Possible forms and equilibria of potassium in soils. (From Tisdale et al., 1993. *Soil Fertility and Fertilizers*, 5th ed., p. 232. With permission of Prentice-Hall, Inc., Upper Saddle River, NJ.)

Table 10.1 Distribution of Feldspar and Mica K in Different Size Fractions of a Haverhill Ap Soil in Saskatchewan, Canada

Particle size (μm)	Total K	Feldspar K	Mica K	% Fraction of K	
		g kg^{-1} soil		Feldspar	Mica
<0.2	21.1	—	21.1	0	100
0.2–2	26.1	0.8	5.3	3	97
2–5	20.1	6.1	14.0	30	70
5–20	17.3	8.7	8.6	50	50
20–50	15.4	9.7	5.7	63	37
50–500	12.7	7.6	5.1	60	40
500–2000	17.3	17.3	—	100	—
<2000+	16.9	6.8	10.1	40	60

From Somasiri et al. 1971. Soil Sci. Soc. Am. Proc. 35:500. With permission of SSSA.

Table 10.2 Potassium Released From K-Bearing Minerals by 0.01 mol L^{-1} Solution of Oxalic and Citric Acids at the End of a 10-Day Reaction Period

	K released (g kg^{-1} of structural K)	
Mineral	Oxalic acid	Citric acid
Biotite	44	11
Muscovite	1.1	0.9
Microcline	2.3	1.4
Orthoclase	2.2	1.2

From Song and Huang. 1983. Agron. Abst. 222. With permission.

studies it was found that, compared with grass sod, 120 years of cropping had greatly reduced the nonexchangeable K content, and it showed that illite was changing to vermiculite.

Nonexchangeable K in soils is generally measured by extracting the soil with 1 N boiling nitric acid and is reported as HNO_3 extractable K. Nonexchangeable, fixed K in soils varies from 50 to 705 mg K kg^{-1} soil (Tisdale et al., 1985), depending upon the nature and amount of clay minerals present.

10.1.3. Exchangeable K

This is the potassium held in the exchange complex of 2:1 layer silicates. Thus soils containing smectite have more exchangeable K than those containing illite, which in turn have more than the soils containing kaolinite (Table 10.3). The amount of exchangeable K in soils may vary from 40 to 600 mg K kg^{-1} soil (Tisdale et al., 1985).

K content

10 %   6 - 8%   4 - 6%   <1%

Mica CEC= 0   Hydrous mica (illite),CEC = 30 - 50   Vermiculite ,CEC=150

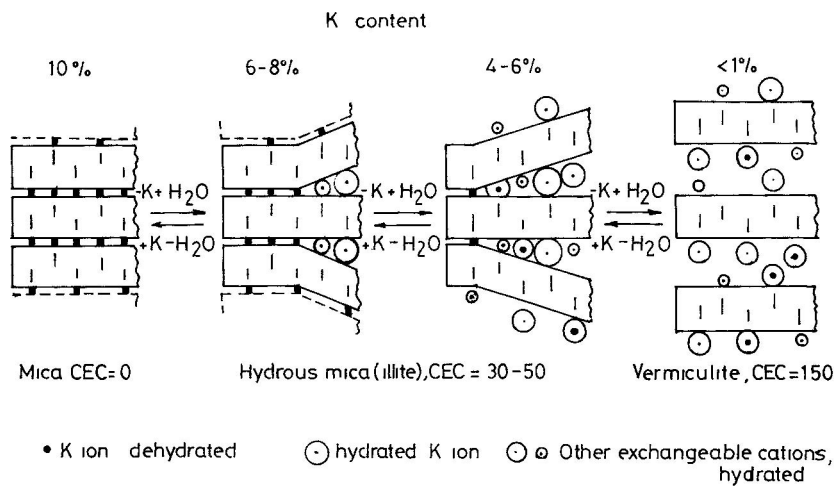• K ion dehydrated   ⊙ hydrated K ion   ⊙ ⊚ Other exchangeable cations, hydrated

Figure 10.3. Schematic weathering of micas and their transformation into clay minerals: a matter of potassium release and fixation. (From McLean, 1979. *Potassium in Soil and Crops*, G.S. Sekhon, Ed., pp. 1–13. With permission of Potash Research Institute of India.)

Table 10.3 Relationship Between Clay Content, Kinds of Minerals, CEC, and Exchangeable Potassium

Soil	Depth cm	Clay %	Minerals[a]	CEC	Ex K
				cmol kg^{-1}	
Houston clay (Vertisol) (Clark County, AR)	0–10	66	MKI[b]	32.9	0.59
Vista coarse, sandy loam (Inceptisol) (San Diego County, CA)	0–8	10.2	IK	17.2	0.20
Cecil fine, sandy loam (Ultisol) (Iredell County, NC)	1–10	10.4	KIV	7.8	0.08

[a] Minerals in the order of dominance.

[b] *M*, Montmorillonite; *K*, kaolinite, *I*, illite, *V*, vermicullite.

From Buol et al. 1980. *Soil Genesis and Classification*, 2nd ed., p. 367. With permission of Iowa State University Press.

Exchangeable K in soils is generally determined by extracting soil with neutral 1 N ammonium acetate and therefore includes water soluble K; the entire value is known as available K in soils (this is the conventional method in soil testing). For the precise determination of exchangeable K, water-soluble K should be determined by extracting soil with distilled water separately and the value obtained should be subtracted from the 1 N ammonium acetate extractable K value to obtain exchangeable K. Normally, water-soluble K is usually a fraction of exchangeable K, except possibly in sandy soils.

10.1.4. Soil-Solution K

This is the potassium present in soil solution and is measured by extracting the soil with distilled water. Amounts of water-soluble K are generally comparable to those determined by electroultrifiltration (EUF_{10}-K desorbed during 10 minutes), a technique proposed by Nemeth (1979) (Sekhon et al., 1992). Water-soluble K in soil may vary from 1 to 10 mg K kg^{-1} soil. Solution K concentration is important for successful crop production. Singh and Jones (1975) at the University of Idaho suggested a critical concentration of 8.7 mg L^{-1} for crops that need lesser amounts of K (tomatoes and beans) and 14.5 mg L^{-1} for crops such as celery and potatoes that have a high K requirement. Levels of water-soluble K below 8 mg L^{-1} may suggest K deficiency.

There is a continuous transfer of mineral K to exchangeable K and fixed K and from there to solution K; the process may reverse to the fixed-K stage under some soil conditions or when heavy K dressings are made. The entire equilibrium may be represented as below:

Nonexchangeable K^{slow} ⇌ exchangeable K^{rapid} ⇌ soil solution K
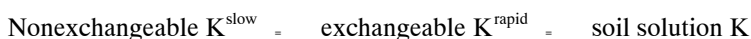
Figures 10.4 and 10.5 show the above relationships for a series of Indian soils. As can be seen from these figures, the release of exchangeable to solution K, as well as from nonexchangeable to exchangeable K, varies from soil to soil and depends much upon the dominant clay minerals present. In general illite- and kaolinite-dominant soils have a larger proportion of water-soluble to exchangeable K than smectite-dominant soils (Figure 10.4). On the other hand, the proportion of exchangeable to nonexchangeable K is greater in smectite-dominant soils than illite- and kaolinite-dominant soils; the proportion for the soils with mixed mineralogical composition is in between (Figure 10.5).

Data on different forms of K, expressed as percent of total K for some Indian soils, are presented in Table 10.4. These data illustrate that the mineral forms of K comprise 92 to 97%, nonexchangeable (fixed K) 2 to 7.5%, and available K (exchangeable and water-soluble) 0.1 to 2% of total K. This general relationship would apply to most soils.

Figure legend (within figure):
- ● Illitic soils $Y = 2.59 + 0.286x, r^2 = 0.88$
- ▲ Mixed-1 soils $Y = 8.24 + 0.13x, r^2 = 0.90$
- △ Kaolinitic soils $Y = 5.58 + 0.072x, r^2 = 0.63$
- □ Smectitic soils $Y = 5.14 + 0.023x, r^2 = 0.60$
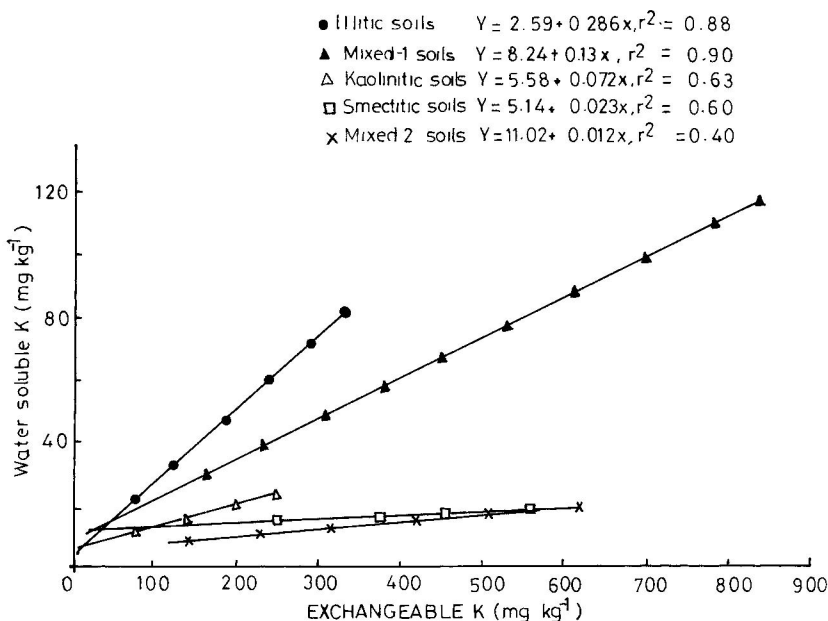- × Mixed 2 soils $Y = 11.02 + 0.012x, r^2 = 0.40$

Figure 10.4. Relationship between exchangeable K and water-soluble K content for different soil groups. (From Sekhon et al., 1992. Special Pub. 3, p. 25. With permission of Potash Research Institute of India.)

10.2. QUANTITY/INTENSITY RELATIONSHIPS

Cations other than K present in soil solution largely influence the effectiveness of solution K for plant nutrition. The activity ratio (AR^K) in a solution in equilibrium with soil therefore provides a better and more satisfactory measure of the availability of K to plants.

$$AR^K = \frac{\text{activity of K}}{\sqrt{\text{activity of Ca + Mg}}} \text{ or } \frac{a_K}{\sqrt{a_{Ca+Mg}}} = (ak)\big/a(Ca+Mg)^{1\,2}$$

where K, Ca, and Mg are expressed in moles L^{-1}.

AR^K is an intensity measure of labile K and indicates the amount of K that is immediately available to plants.

However, as pointed out earlier, solution K tends to be in equilibrium with exchangeable K, which is the total quantity (Q) of K available in soil. The Q/I concept in potassium was developed by Beckett (1964ab) and is in line with the ratio law enunciated by Schofield (1947). This relationship is explained in Figure 10.6, which shows that the different available quantity (Q) in two different soils can have the same intensity of K (AR^K) depending upon the
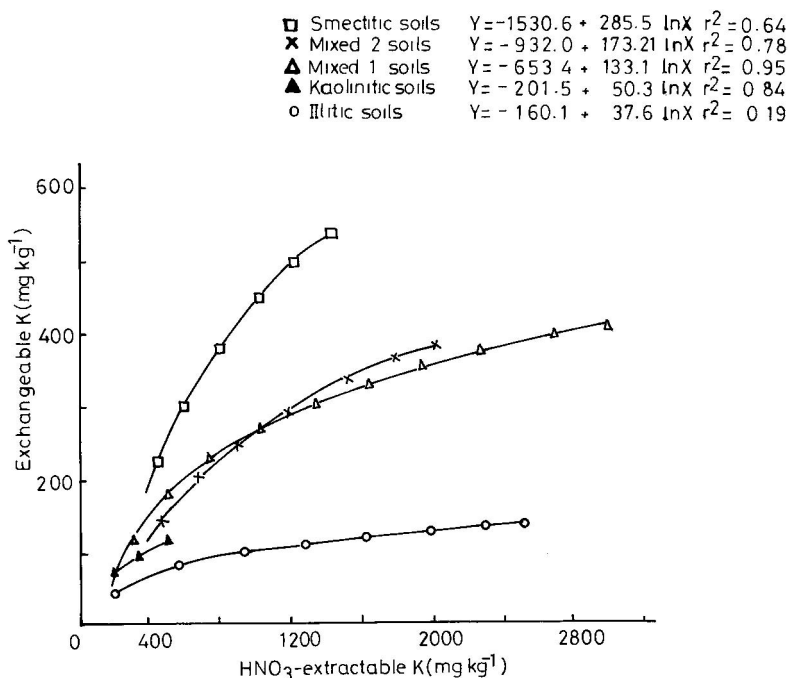
⊡ Smectitic soils	$Y = -1530.6 + 285.5 \ln X$	$r^2 = 0.64$
✗ Mixed 2 soils	$Y = -932.0 + 173.21 \ln X$	$r^2 = 0.78$
△ Mixed 1 soils	$Y = -653.4 + 133.1 \ln X$	$r^2 = 0.95$
▲ Kaolinitic soils	$Y = -201.5 + 50.3 \ln X$	$r^2 = 0.84$
○ Illitic soils	$Y = -160.1 + 37.6 \ln X$	$r^2 = 0.19$

Figure 10.5. Relationship between HNO_3-extractable and exchangeable K content for different soil groups. (From Sekhon et al., 1992. Special Pub. 3, p. 27. With permission of Potash Research Institute of India.)

soil's mineralogical makeup, which largely determines its CEC and K saturation of the exchange complex. When a certain quantity of K (ΔQ) is removed from the soil solution by plants (or leaching), the change in intensity (ΔI) is much greater in soil B (sandy soil with low CEC) than in soil A (clayey soil with higher CEC).

The ratio (slope) $\Delta Q / \Delta I$ is referred to as the potassium buffering capacity (PBC^K). A large PBC^K signifies a good K-supplying power of a soil, while a small value suggests the need for frequent fertilization.

There are two more points to be noted in Figure 10.6:

1. The value of AR^K when ΔK is zero represents the current status of soil K.
2. The variation from the linearity of the curve as it approaches an activity ratio of zero (dotted extension of the curves below the x-axis) is labile K; it is a rough measure of the potential for a K source to exchange available K from currently unavailable sources. It may be noted that soil B has a much smaller potential than soil A.

Table 10.4 Forms of Potassium Expressed as Proportion of Total Potassium in Different Soils

Soil	Form of K (% of total K)		
	Water-soluble	Exchangeable	Nonexchangeable
Alluvial			
Calcareous illitic (8)[a]	0.12	0.28	7.52
Acidic kaolintic (2)	0.32	0.78	2.34
Vertisols and vertic type			
Smectitic (7)	0.25	2.12	5.56
Red and Laterite			
Kaolintic (5)	0.19	0.49	3.14

[a] Numbers in parentheses refer to the number of soil series.

From Sekhon et al. 1992. Special Pub. 3, p. 23. With permission of Potash Research Institute of India.

10.3. POTASSIUM FIXATION

Potassium fixation is defined as the conversion of soil solution or exchangeable K into nonexchangeable forms and was once considered a negative soil property causing a drastic reduction of plant available K. However, this view is no longer held and K-fixation is considered beneficial because it reduces K losses by leaching and luxury consumption, yet it maintains a potentially available K pool (Pearson, 1952). In most well-fertilized soils, the nonexchangeable K–exchangeable K equilibrium is dynamic and fertilizer K that is fixed on addition is also available for more immediate release (Bertsch and Thomas, 1985). This is evidenced by the observation that the release of nonexchangeable K by intensive cropping results in increased fixation of subsequently applied K (Munn and McLean, 1975).

A number of factors affect potassium fixation in soils. These are briefly discussed.

10.3.1. Clay Minerals

The amount of K fixed by a soil depends much upon its clay content. Both quantity and quality are important, but in general, the greater the clay content, the greater the K fixation. Regarding the kind of clay minerals, illite,
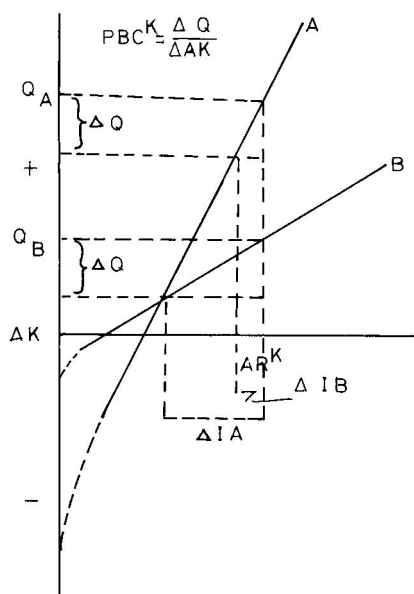
Figure 10.6. Q/I relationship in soil potassium. Soil A represents a fine-textured soil rich in illite and smectite, while Soil B represents a coarse-textured soil having kaolinite as the dominant mineral. (Adapted from Bertsch and Thomas, 1985.)

weathered mica, vermiculite, smectite, and interstratified minerals fix K, while kaolinite fixes very little (Figure 10.7).

10.3.2. Soil pH

In acid soils the presence of Al^{3+} and aluminum hydroxide cations and their polymers occupy the K-selective binding sites on clay minerals. Also, the presence of hydroxyl aluminum-iron interlayer groups under acid conditions prevents the collapse of silica layers in expanded clay minerals and therefore prevents the entrapment of K. Thus when pH of acid soil is raised, it affects K-fixation in two complementary ways: (1) precipitation of Al^{3+} due to higher OH^- ion concentration and (2) progressive hydroxylation of monomeric and polymeric forms of hydroxyl-Al ions, whose positive charge is gradually neutralized. Liming will thus increase K-fixation, especially in temperate-region soils where 2:1 layer silicates having Al^{3+} dominate. Liming may have little effect on K-fixation in tropical soils where kaolinite dominates (Ritchey, 1979; Malavolta, 1985).

As already discussed in Chapter 4, raising soil pH above neutrality increases the negative charge on oxides and hydroxyoxides of iron and aluminum, which results in increased adsorption of K ions and consequent reduc-
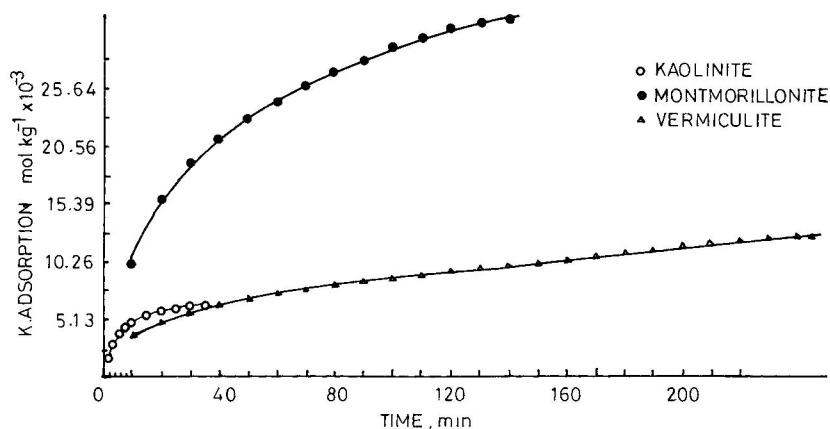
Figure 10.7. Potassium adsorption versus time in pure systems. (From Sparks and Jardine, 1984. Soil Sci. 138(2):115–122. With permission of Williams & Wilkins.)

tion in soil solution K (Figure 10.8). Thus the overall effect of an increase in soil pH is increased K-fixation (Figure 10.9).

Thus liming in general lowers the concentration of K in soil solution. In terms of the Q/I relationship discussed earlier, the AR^K value is reduced (Mielniczuk, 1977), as is shown in Figure 10.10. However, in both soils 1 and 2 in this study, the K-buffering capacity (PBC^K), that is, $\Delta Q/\Delta I$ or the slope of the linear curve, increased from 0.08 to 0.24 in soil 1 and from 0.84 to 1.35 in soil 2.

The overall effect of liming is beneficial because it reduces the leaching of K and it prevents the luxury consumption of K. Even on very acid tropical soils the effects of temporarily lowering K in soil solution (AR^K) are over-compensated by the removal of the restrictive effect of Al on root growth and vigor (Tisdale et al., 1985). This is supported by data on K uptake studies by crops. For example, Fageria et al. (1989) showed that the K concentration in alfalfa shoots grown on an acid inceptisol from Tennessee increased with liming.

10.3.3. Wetting and Drying

Data on K-fixation after wetting or drying are presented in Table 10.5. These data show that despite great differences between temperate and tropical soils, K fixation was 2 to 3 times greater after drying than after wetting (Malovolta, 1985). Thus air drying of soils high in exchangeable K will result in fixation and a decline in exchangeable K. This needs to be considered when interpreting soil test data for available K, which is the sum of exchangeable and water-soluble K and is generally determined by extraction with 1 N ammonium acetate after air drying the soil samples.
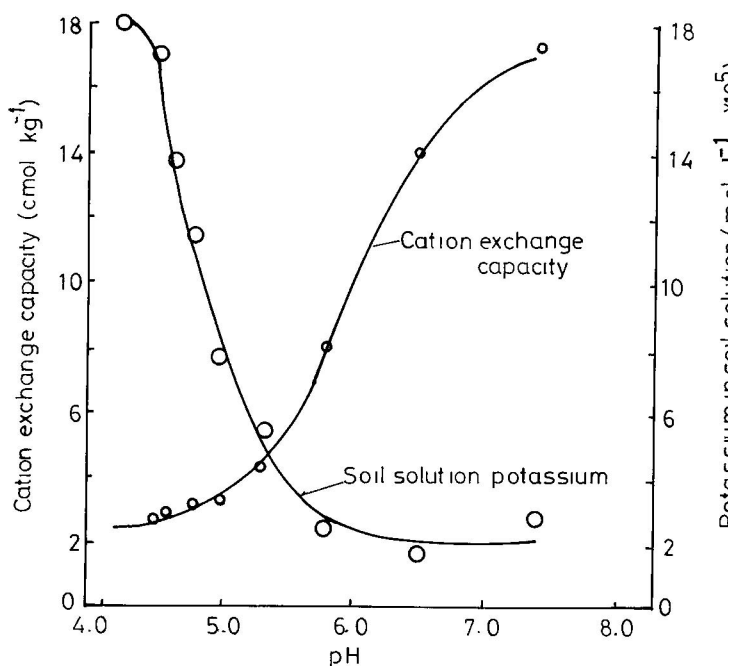
Figure 10.8. The influence of increased pH resulting from lime additions on the pH-dependent, cation-exchange capacity of a soil and the level of potassium in the soil solution. As the cation-exchange capacity increases, some of the soil solution potassium is attracted to the adsorbing colloids. (From Brady, N.C. 1990. *The Nature and Properties of Soils,* **p. 376. With permission of Prentice-Hall, Inc., Upper Saddle River, NJ.)**

However, drying of field-moist soils, particularly subsoils, with low to medium levels of K is reported to increase exchangeable K. This has been attributed to the exfoliation of edge-weathered micas and exposure of inter-layer K.

10.3.4. Potassium Fertilization

Adding large amounts of fertilizer K generally results in increased K fixation because solution K concentration is greatly increased, pushing the equilibrium between soluble and fixed-K toward the fixed K pool.

10.3.5. Freezing and Thawing

Alternate freezing and thawing may result in increased exchangeable K in some soils; however, the reverse may also happen in illitic soils having high exchangeable K (Tisdale et al., 1985).
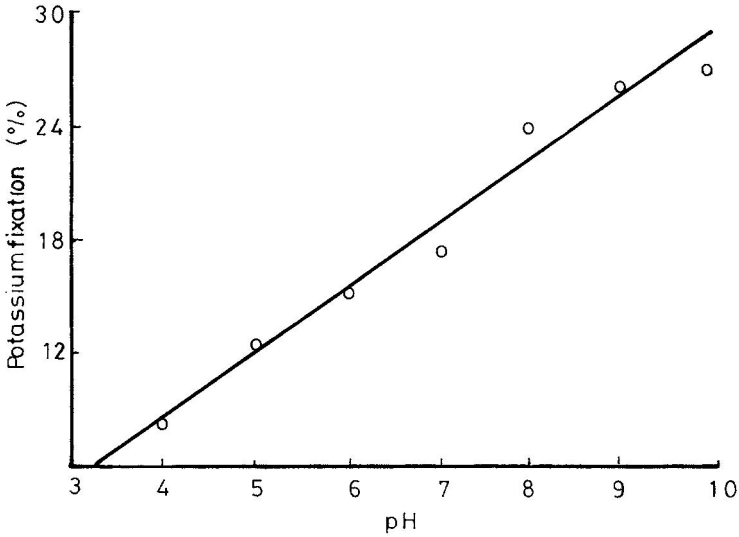
Figure 10.9. The effect of pH on the fixation of potassium soils in India. (From Grewal and Kanwar, 1976. *Potassium and Ammonium Fixation in Indian Soils — Review,* **Indian Council of Agricultural Research, New Delhi.**
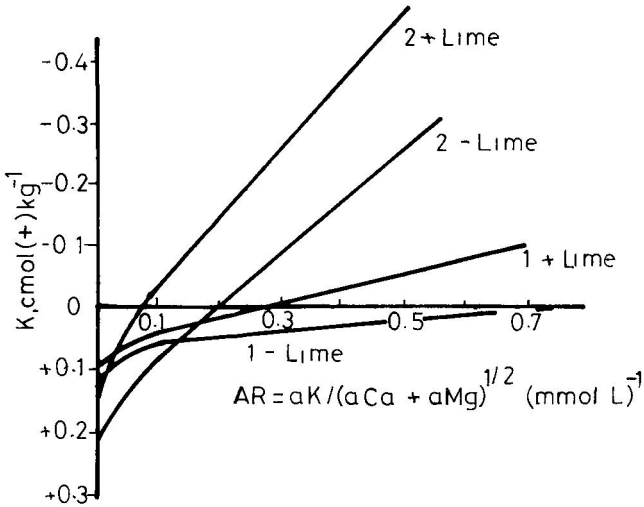

Figure 10.10. Effects of lime on Q/I values of Brazilian soils. (Mielniczuk, 1977. Rev. Bras. ci Solo 1:55–56.)

**Table 10.5 Potassium Fixation After the
Wet and Dry Methods[a]**

| Region | K fixation % | |
	Wet	Dry
Temperate		
Range	Trace–63	15–95
Average	25	68
Tropical and subtropical		
Range	2–40	15–67
Average	17	24

[a] Shaking with K^+ solution is the wet method; drying of the
soil with K^+ solution at 80°C is the dry method.

From Malovolta 1985. *Potassium in Agriculture*, R.D. Munson, Ed., p. 163. With permission of ASA.

10.4. LEACHING OF POTASSIUM

Potassium leaching from a soil fluctuates in accordance with the quantity, timing, and intensity of rainfall. For example, in a study on a sandy soil, K leaching was 19 kg K ha^{-1} yr^{-1} in dry years but increased to 57 kg K ha^{-1} yr^{-1} in wet years (Jurgens-Gschwind and Jung, 1979). Despite low K content in tropical soils, considerable K may be lost by leaching due to heavy rains. For example, McColl (1970) reported a loss of 52 kg K ha^{-1} yr^{-1} from forests of Costa Rica receiving an annual rainfall of 380 mm yr^{-1}. Godefroy et al. (1975) in the Ivory coast (oxisols on Schists) estimated that 50 to 60% of the K fertilizer (1100 kg K or 1325 kg K_2O yr^{-1}) applied to bananas (*Musa paradisiaca* L.) was lost by leaching. Ritchey (1979) showed that 1 month after burning the vegetation for clearing the land in Peru, the exchangeable K content to a depth of 30 to 50 cm increased three times the preclearing value (Figure 10.11). However, after 6 to 10 months, the K level returned to the original value due to excessive leaching of K.

Liming generally reduces K leaching (due to increased K fixation as discussed earlier). For example, Shaw and Robinson (1960) reported K leaching losses in a loam soil of 55 kg ha^{-1} on the unlimed soil (pH 4.5) and 21.6 kg K ha^{-1} with an application of 12.5 Mg dolomite limestone ha^{-1}.

10.5. POTASSIUM FERTILIZERS

There are two major potash fertilizers, namely, potassium chloride or muriate of potash (KCl) (50 to 52% K or 60 to 63% K_2O) and potassium sulphate (K_2SO_4) (40 to 44% K or 48 to 53% K_2O). Both of these fertilizers
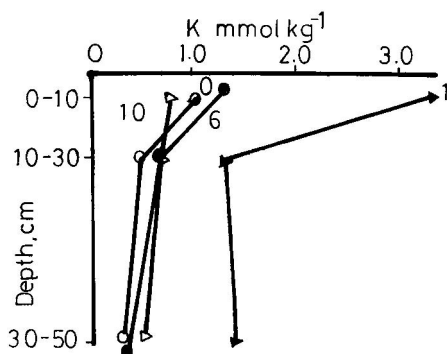
Figure 10.11. Extractable K measured before burning (0) and 1, 6, and 10 months after jungle vegetation in Peru. (From Ritchey, 1979. Cornell Int. Agric. Bull. 37, Cornell University Press.)

are mined as minerals in Canada, the United States, and Germany. Production of potassium chloride is about 20 times that of potassium sulphate. Potassium chloride therefore makes up the bulk of fertilizer K consumed in the world. Potassium sulfate also contains about 17% S, and this is an advantage for areas having sulfur deficiency.

Small amounts of potassium are also marketed as double salts of potassium and magnesium. Kainite (KCl Mg SO_4 $3H_2O$) contains 15.99% K (19.2% K_2O), 9.94% Mg, and 13% S. Langbeinite, which is marketed as K-Mag or Sul-Po-Mag, has a theoretical composition of 18.85% K (22.7% K_2O), 11.71% Mg, and 23.18% S. These materials have the advantage of supplying Mg and S in addition to K.

Very small amounts of potassium are applied as potassium nitrate (36.7% K or 44% K_2O) and potassium phosphate (13 to 26% P or 30 to 60% P_2O_5 and 25 to 41.7% K or 30 to 50% K_2O). In addition, in the United States, some potassium is applied as potassium polyphosphate (17.5 to 26% P or 40 to 60% P_2O_5 and 18.3 to 40% K or 22 to 48% K_2O).

10.5.1. Choice of K Fertilizers

Potassium is applied to a majority of crops as potassium chloride or muriate of potash. The recognition that the Cl^- ion, quite apart from its role in plant nutrition, suppresses some disease organisms, such as those causing take-all of wheat and stalk-rot of corn, and may influence the selection of muriate of potash as a source.

Potassium sulphate is commonly applied to tobacco because excessive chloride uptake may impair the burning quality of the cured leaf. Superiority of potassium sulfate for potatoes is suggested for higher specific-gravity and starch yields. Potassium sulfate is also preferred on soils having S deficiency, for example, for alfalfa in Wisconsin and Nebraska.

10.6. EFFICIENT USE OF POTASSIUM FERTILIZERS

For efficient use of potassium fertilizers, one has to consider the following: (1) soil factors; (2) weather factors, especially precipitation; and (3) crop factors. Soils having 2:1 layer silicates and interstratified minerals can fix appreciable K and therefore these soils do not pose a serious leaching problem. On the other hand, sandy soils and soils having kaolinite as the dominant mineral, as in tropical and subtropical soils (which are also in high-rainfall regions), present serious leaching problems (already discussed under leaching in this chapter). Method and time of potassium fertilizer application therefore assume considerable importance. Fageria (1982) found that in upland rice in Brazil, application of moderate amounts of K (30 to 45 kg ha^{-1}) in the planting furrow gave the same yield as twice as much K broadcast and incorporated in the soil. Application of K in the planting furrow is advantageous when soils are poor in K and the levels applied are low to moderate; application of high rates in the planting furrow may result in a localized salinity problem, causing seedling injury. On soils susceptible to K leaching, broadcast application followed by incorporation to the 20-cm depth is considered superior to band application (Ritchey, 1979). Application of 100 kg K ha^{-1} by incorporation raised exchangeable K by 1.2 mmol kg^{-1} soil, while banding 80 kg K ha^{-1} in a band 8 cm wide every 80 cm increased exchangeable K to 10 mmol K kg^{-1} soil in the bands, which the soil was not able to retain. This resulted in excessive K-leaching. On the other hand, with high-K-fixing soils and low to moderate levels of K application, banding is advantageous for row crops such as corn.

Split application of K (part at planting and part side-dressed later) is recommended to avoid salinity effects and leaching losses both in annual and perennial crops. The beneficial effects of split application of K have been reported in a number of crops and countries: lowland rice in India, Japan, Bangladesh, and Indonesia; bananas and pineapple (*Ananes cosmosus* [L], Merr) in West Africa; and coffee, sugarcane, cotton, and cassava (*Manihot essulenta*, Crantz) in Brazil.

Genotypic differences in crop species with respect to K nutrition are well known. For example, Glass and Perley (1980) detected fairly large differences in K$^+$ influx in barley varieties as early as 6 days after germination. There is now a growing interest in identifying plant genotypes that can tolerate stresses to different plant nutrients (including potassium), and a symposium on this topic was organized at the University of Nebraska in Lincoln in 1993 under the auspices of the INTSORMIL, a sorghum/millet collaborative research support program of the U.S. Agency for International Development (USAID).

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